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DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXIV, No. 1 JANUARY, 1930 WHOLE No. 190

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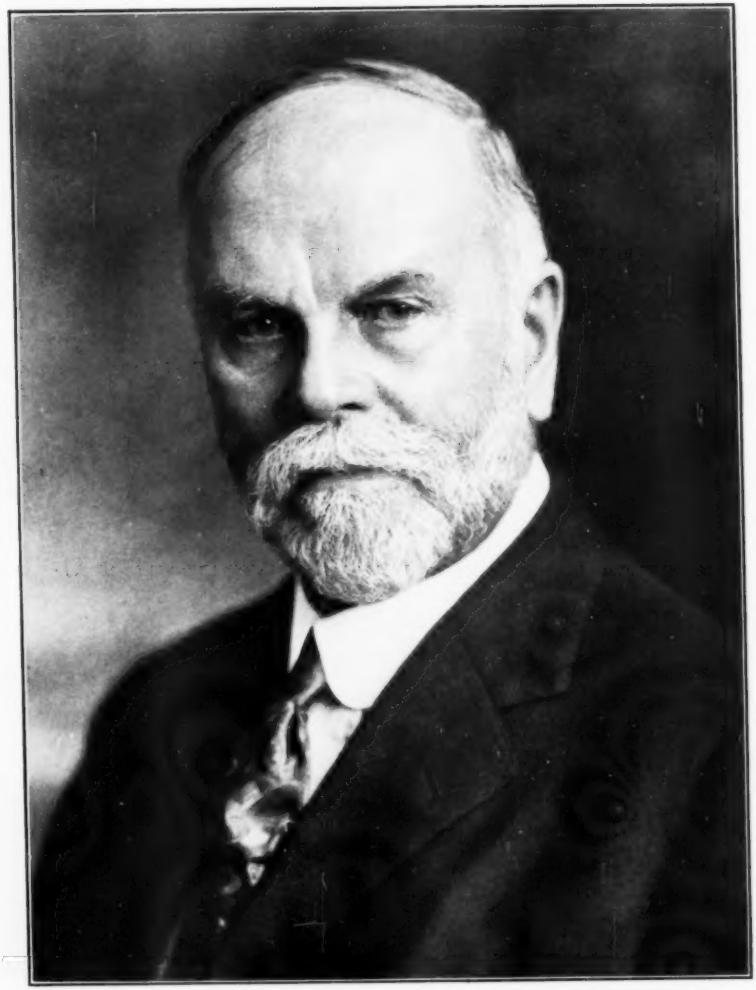
PLATE I



WORCESTER REED WARNER
1846-1929

THE JOURNAL
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A Happy New Year

Brightly sparkling, stars are shining
Golden lights of a distant Way;
Shedding Joy, with Love combining,
Guiding us to Supernal Day:
May the New Year, now approaching,
Bring us a Twelve month- sorrow-free;
Stellar rays on hearts encroaching,
Light- with Love, both, for thee and me!

Softly gleaming, signs in Heaven,
Tender thoughts of a gentle Grace;
Yielding Love- all faults forgiven-
Drawing us near to see His Face,
May the New Year and its treasure
Fill our hearts with a Joy sublime;
Grant us Love, in fullest measure,
Now, and for all Eternal Time!

Kilbee Gordon

WORCESTER REED WARNER

By C. A. CHANT

For many years the firm of Warner and Swasey has been familiar to the astronomical world and the passing away of one of its original members causes wide-spread regret.

Worcester Reed Warner was born on a farm near the village of Cummington, between Northampton and Pittsfield, Massachusetts, on May 16, 1846. The poet William Cullen Bryant was also a native of Cummington, and both men traced their lineage back to the Mayflower pilgrims. Worcester Warner's father, Franklin J. Warner, was an exceptionally prosperous farmer, and his mother, whose maiden name was Vesta Wales Reed, was a lover of scientific books and was fond of mechanical things. Thus the son apparently inherited his business ability from his father and his taste for mechanics from his mother. He was early drawn to science by his mother's books, and his astronomical inspiration came from O. M. Mitchel's famous old book, "The Orbs of Heaven, or Planetary and Stellar Worlds", which was presented to him by his parents.

The boy attended the village school, and, in order to earn a little money to assist in making some experiments, he built the fires in the schoolhouse stove at 8 o'clock each morning. For this he received $2.00 a term. He had a workshop over his father's carriage shed, and one of his earliest productions here was a lathe which he constructed from odd materials lying about. At school he was fond of mathematics and history. At the age of nineteen he completed his formal education with a three-months term under G. Stanley Hall, then a student at Williams College, later a distinguished psychologist and for twenty-five years president of Clark University, Worcester, Mass.

Worcester Warner was not inclined to farming as his life work. While visiting his uncle in Boston in the autumn of 1865 he saw a four-line advertisement for a boy to work in the drafting room of the American Safety Steam and Engine Co. Answering it in person, he was dismayed to see about a hundred smart city lads in line

ahead of him. He thought he would have little chance for the position. The head of the office was George B. Brayton, one of the most eminent engineers of his time. He was attracted by the appearance of the tall boy and, after asking some questions dealing with mechanical problems, he hired him for $5 a week.

It is stated that the president of the company was somewhat disgusted at the choice made, but the engineer recognized the promise of the boy. Indeed he took pains to cultivate Warner's acquaintance, and next spring when the offices of the company were moved to Exeter, New Hampshire, he took him along. Besides drafting in the office, he also worked in the shop and there he first met Ambrose Swasey, whom he described as "the brightest of the lot," and they soon became good friends. Mr. Swasey was born and educated in Exeter and had entered the machine shop a year before this.

In the spring of 1869 the two young men planned to begin their real life work together. Warner wrote to four firms regarding employment and received favourable replies from all. Together they visited the well-known firm of Pratt and Whitney, builders of machine tools, at Hartford, Conn., and after Amos Whitney showed them through the works they entered the firm's employment. Although there were some five hundred employees ahead of them, in less than two years each of the two young men was made a foreman. Eventually Mr. Warner had charge of a machine-tool-building department while Mr. Swasey had charge of the gear-cutting department. For eleven years they continued with Pratt and Whitney, and, although their daily pay was never more than $3, they managed to accumulate a joint capital of $12,000. During this time Mr. Warner devoted himself to scientific studies and as a recreation he made experiments in telescope building.

In 1873 there was an industrial exhibition at Boston and, on account of his winning personality, Mr. Warner was placed in charge of the Pratt and Whitney display of machinery. He played his part with great success. He placed a fast screw-cutting machine near the aisle and kept it in active operation. It was a great attraction to visitors to whom he liberally distributed samples of its work. The result was, the company received the only gold medal which was awarded. Three years later the Centennial Exhibition was

held in Philadelphia and Mr. Warner had charge of the firm's exhibit. He spent six months there. In 1878 he paid his first visit to Europe. One of the places in England which he was anxious to see was the famous Whitworth works at Newcastle-on-Tyne, and he made a great effort to obtain, through influential friends, a pass to the shops, but he was unsuccessful. So he went boldly alone to the works and by his intelligence and sunny ways he so impressed the Whitworth officials that he was conducted through the works.

In 1880 Mr. Warner and Mr. Swasey decided to start a business of their own, and, believing that the west was a virgin field for the production of high-class machine tool devices, they began their first business together in Chicago. But they remained there only a few months as they could not secure the necessary number of skilled mechanics which they required. During this short time, however, they received orders for several small telescopes. After a survey of Cleveland they decided to settle there, and in 1881 they built the first part of the plant which has since grown to immense proportions. In addition to their own $12,000, they borrowed $9,000 to put into the business. That was the only borrowed capital they ever needed.

During the last fifty years the firm has become famous for two very different products—astronomical telescopes and turret lathes. From his early construction of telescopes Mr. Warner became convinced that the increasing size of these instruments demanded that the mounting should be a real engineering construction, rigid in support, precise in its motions and convenient to use. That he was right in his views is shown by the firm's outstanding achievements. The first great structure was the 36-inch Lick instrument, after which followed the 40-inch Yerkes, the 72-inch reflector at Victoria, B.C., the 60-inch for the Argentine National Observatory, a similar one for the Ohio Wesleyan University and many others of smaller size. Mr. Warner expressed special satisfaction with the design of the 72-inch and believed it would be the standard for a hundred years. The firm was equally successful in producing range-finders, gun-sights, field telescopes and other equipment for the United States Government. The excellence of the design and the precision

in the construction of the firm's products owe much to Mr. Warner's engineering ability and mechanical skill, and their wide introduction into industry can be attributed in considerable measure to his personality and business foresight.

The Warner and Swasey Company was incorporated in 1900. Until that time the business had been conducted without any written agreement between the two men—a splendid testimony to the integrity of two honourable men.

In 1911, at the age of 65, Mr. Warner retired from active management of the business, and, after investigating various places in the eastern states, he built a charming home at Tarrytown, N.Y. Here he erected an observatory with a 6-inch refractor mounted in the Warner and Swasey manner, but the "dome" is in the form of an automobile top which can be folded back. This instrument he often placed at the service of the educational institutions in the neighborhood.

During the thirty years Mr. Warned lived in Cleveland he gave much attention to the financial and civic affairs of the city. He was director of several financial corporations and was a trustee of Western Reserve University and Case School of Applied Science. He was a member of several astronomical organizations and it was at meetings of the American Astronomical Society that the writer became acquainted with him. In 1897 he was given the degree of Doctor of Mechanical Science by the Western University of Pennsylvania, and in 1925 that of Doctor of Engineering by Case School of Applied Science.

In 1920 Mr. Warner and Mr. Swasey presented to Case School an observatory equipped with a 9-inch telescope.

That Mr. Warner was interested in assisting astronomers in the problems relating to equipment is exemplified by the efforts he put forth at the time Dr. Henry S. Pritchett, now president of the Carnegie Foundation for the Advancement of Teaching, was professor of astronomy at Washington University, St. Louis, and had succeeded in securing funds for a 6-inch telescope. Mr. Warner saw in this installation an opportunity for encouraging a promising young astronomer and went himself to St. Louis to erect the instrument, rather than trusting the task to a subordinate. Dr. Pritchett

has repeatedly referred to the inspiration he received from this act of kindness and has stated that not only were his problems at that time solved, but his interest in science was greatly strengthened and his career largely shaped by that experience.

In 1890 Mr. Warner married Miss Cornelia F. Blakemore, of Philadelphia, who thereafter was his constant companion in the activities of his life, including his travels abroad. Mrs. Warner, with their daughter, Miss Helen B. Warner, survive him.

Mr. and Mrs. Warner contributed liberally to educational, charitable and religious institutions, including benefactions to the School of Art and the University Hospitals at Cleveland, to the American College at Beirut, Syria, and to Western Reserve University; also a Community House and water-works system for Cummington, the Warner Library at Tarrytown; and Mr. Warner gave to Case School the Worcester Reed Warner Laboratory.

Mr. and Mrs. Warner made several extended trips abroad, sometimes accompanied by a number of relatives and friends. In the winter of 1915-16 they visited Japan and China, and the informal letters written by Mrs. Warner to friends at home were later printed in a small volume for private circulation. The frequent references, not just to court receptions and national monuments or celebrations, but also to colleges and schools, usually connected with missions, indicate their breadth of interest.

Early in May, 1929, Mr. Warner, accompanied by his wife and daughter, left on his ninteenth European trip. They had visited Switzerland and Italy and had begun their trip through Germany when Mr. Warner was taken ill at Eisenach and after a brief illness he died on June 25.

For much of the information contained in the above sketch the writer is indebted to Mr. Warner Seely, nephew of Mr. Warner and at present secretary of the Warner and Swasey Company.

RADIO TALKS ON ASTRONOMY OVER CFCT

By W. E. Harper

XX. Heat from the Stars

(October 9, 1929)

The title which has just been announced may seem somewhat fantastic to many who may be listening in; but as the sun gives us heat and the stars are also suns, shining by their own light, it is not altogether unreasonable to enquire if they also send us any heat.

In a former talk I told you something of the immense amount of heat sent out by the sun. By careful measurements it is found that the amount falling every minute on a square centimetre of the earth's surface, an area about one-quarter the size of a postage stamp is sufficient to raise the temperature of 1.94 grams of water through 1° Centigrade. Of recent years it has been learned that this amount varies over a small range, so that the figure given is only an average value. While such figures may not mean much to the average person it will at least convey the idea that the strength of the sun's rays and their warming power are very accurately known.

But the rays we see as light and those that we feel as heat are only a portion of the total energy pouring out from the sun. All such radiations are thought of as coming to us with equal velocities, namely that of light, but coming in waves whose lengths from crest to crest vary with the character of the radiation. Light-waves range from 1/70,000 of an inch for the blue to 1/35,000 of an inch for the red. Converting these into the units science often uses, we say that ordinary light ranges in wave-length from 0.4 to 0.8 microns. Radiations of wave-length just shorter than these are spoken of as ultra-violet, whilst at the other end, and known as the infrared, are waves from 0.8 to 300 microns in length. It is these latter waves, particularly those from 8 to 14 microns in length that are the heat waves. Incidentally the radio waves that carry my voice out to you are of much greater wave length than heat waves.

While it is comparatively easy to measure the radiant energy from the sun it becomes exceedingly difficult to measure the same in the case of the stars, owing to the almost infinitestimal amount they send us. Very delicate thermometers are necessary and the principle of these thermometers requires a word of explanation. It is found that when light falls on certain metals, like tin or bismuth or antimony, the electrical resistance of these metals is changed by different amounts. Long years of experimental work have shown that if you place a small blackened receiver at the junction of two such dissimilar metals and cause light to fall upon the receiver, then a feeble electric current will be set up. The current is proportional to the energy incident upon the receiver and can be measured by a sensitive galvanometer. Such an instrument is more effective when enclosed in a vacuum, and it is further learned that the smaller the receiver and the metal strips can be made the more sensitive the instrument becomes. So nearly perfect has modern workmanship now become that a complete receiver and metal strips has been constructed weighing only 1/1000 of a drop of water.

With such a delicate heat-measuring device, or thermo-couple as it is called, measures have been made of the heat energy sent us by several of the brighter stars. The one which sends us most is the well known star, Betelgeuse, in Orion. This star received much publicity nine years ago by reason of its being the first one whose diameter was measured by the interferometer, a newly devised instrument for such purposes. Betelgeuse is a giant reddish star with a diameter about 300 times that of our own sun, though of exceedingly low density. When its rays are concentrated by the Mount Wilson 100-inch telescope on one of these tiny thermometers the temperature of the receiver is raised only 0.015° Centigrade. This, I have just stated, is the star which sends us the most heat energy. At the other extreme, among the stars of low heat energy, is one numbered 4342 in the catalogue of Boss, which in a similar way raises the temperature of the receiver only 0.000,009° Centigrade. To the lay mind a change of nine-millionths of a degree in temperature may seem impossible to conceive of, much less measure, but it would appear to be within the actual working limits of this very delicate electrical thermometer.

The further interesting fact is brought out that reddish stars send us more of such heat radiations than bluish stars. That is to say if we have two stars of the same apparent brightness to the eye, one red and the other blue, the reddish one will affect the sensitive receiver much more than the blue. A good example of this may be cited in the case of the bluish star Sirius, visible from these latitudes low in the southern skies in the winter evenings. It is the brightest star in the heavens, out-shining Betelgeuse just mentioned thirteen-fold. Nevertheless, when heat radiations are considered it has to take third place, being preceded not only by Betelgeuse but also by Antares, a star of similar type but of even larger dimensions than Betelgeuse.

We know also that there are stars almost identical in color, or type, but which, nevertheless, fall into two great classes. In one class are giants hundreds of times as luminous as our sun; in the other, dwarfs, whose real luminosities are much less than that of our sun. It might be thought that if such a giant were situated far enough away in space to appear to us as of equal brightness with a dwarf that they would register the same deflection on the thermometer. Not so; the giants send us considerably more heat than the dwarfs and this corroborates knowledge of their physical conditions obtained in other ways. The giants are at lower surface temperatures and consequently send us more of the long wave-length radiations than is possible with the hotter dwarfs whose radiations are confined more to the shorter wave-lengths.

If we considered the total radiation of all stars down to magnitude 6.25, which is much below that visible to the naked eye, it would require from 100 to 200 years for sufficient stellar energy to fall on a square centimetre of the earth's surface to raise the temperature of one gram of water through 1° Centigrade. In a future talk, I may have something to say regarding the way this delicate thermometer has brought us knowledge of the temperatures on the surfaces of the planets, particularly in the case of Mars whose habitability has often been discussed.

XXI. The Planet Jupiter

(November 13, 1929)

If we look out to the northeast sky on any of these nights, about this hour, we will notice a bright object which might be mistaken for a very bright star but which is instead the largest of the planets. The planets are bodies exceedingly small as compared with the stars and are not self-luminous as are the stars but shine merely by sunlight reflected from their surfaces. Jupiter is the largest of the planets and for the next four or five months will be the most conspicuous of the heavenly bodies. At the moment it is on the northeastern sky about half-way up to the zenith. It will cross our meridian a little after one o'clock to-night and increasingly earlier as the days go by so that it is in a very favourable position for observation.

At some later date I may go more fully into the origin of Jupiter and the other planets which revolve about the sun as a centre. Suffice it to say here that millions of years ago the planets formed a part of the central sun, but through disruptive forces they were torn from it and now revolve about the central luminary in various periods of time. The period of revolution of our own planet is one year, that of Jupiter is 11.86 years. Our mean distance from the sun is 93,000,000 miles; that of Jupiter is 5.2 times as great or 483,000,000 miles. The figures are, of course, given in round numbers. Moreover, when Jupiter is on the side of the sun opposite to that on which we are, its distance from us is the sum of these two figures, namely 576,000,000 miles; whilst when we are on the same side, as at present, its distance from us is the difference of the two or 390,000,000 miles. Since light diminishes as the square of the distance one can well understand how much brighter it is at a distance of 390, than at a distance of 576 millions of miles.

If our planet is blessed with one moon to illuminate the darkness of night, surely Jupiter must be greatly blessed. It has nine moons, four of which are quite large and which were in fact discovered by Galileo when he turned his first crude telescope to the planet. Within a few weeks after his first observation he had noted

that they revolved about the planet and had even roughly determined their periods of revolution. The closest one to the planet takes 1¾ days, the fourth one 16 2/3 days, to make the circuit. The remaining five are too faint to be seen with an ordinary telescope but these original four can be seen even by an ordinary opera glass. If one has a small telescope it is an interesting pastime to plot their positions, from night to night, relative to the planet itself and thus repeat Galileo's discovery of their periods of revolution. It will be found that the four are always approximately in a straight line. They may happen to be all on one side of the planet or some on one side and some on the other, if indeed one is not actually hidden behind the planet itself.

From the motions of its satellites the mass of the planet can be very accurately determined and it is found to be 317 times that of the earth. Its mean density is 1.34 times that of water, about the same as that of the sun but only one-quarter as great as the density of our earth. It is only natural to suspect that this density is not uniform throughout its depth but that it is much greater than the mean value in the interior of the planet and consequently much less on the outside.

Our own planet rotates on its axis once in 24 hours, giving us day and night. Although Jupiter is 1300 times as large it rotates in a much shorter period of time, approximately 9h 55m. All parts of its surface do not rotate with the same angular velocity; the equatorial portions perform 85 rotations to every 84 of the polar regions. The change in velocity from the equator to the pole is not uniform however, as is the case with the sun. There appear to be a number of different zones, each with its own rate of rotation, the general average being one complete rotation in 9h 55m as stated above.

This rapid axial rotation, coupled with its low density is doubtless the cause of the planet departing from the spherical form. Our own earth, as a matter of fact, is not a perfect sphere, the equatorial diameter being 27 miles greater than the polar. In the case of Jupiter the flattening is about 20 times as marked as its equatorial diameter is 88,640 and the polar 82,880 miles. One does not require delicate micrometers to detect this difference; it immediately strikes the eye when we look at the planet through a telescope.

In addition to the planet being bulged out at the equator it will be noticed that streaks or belts parallel its long diameter. These are atmospheric markings caused also by the rapid axial rotation. A point on the equator of the earth is moving at approximately 1000 miles per hour; a similar point on Jupiter is moving 28,000 miles per hour and naturally its atmosphere is drawn out into streaks which show as dark bands upon its surface. A closer examination shows that these belts have a number of prominent markings which partake of more or less regular shapes. The most outstanding one is the Great Red Spot, so called from its colour, which has been observed for the past two hundred years. It is oval shaped with a width of some 7,000 and length of 30,000 miles and it has, with minor changes, persisted through all these years, thereby suggesting some deep seated origin.

At its distance from the sun Jupiter receives only 1/27 of the heat we do from the parent body. Unless this were supplemented by sources from within the planet itself its surface would be frozen over. The earliest views were, then, that there was such an internal source of supply, that Jupiter's core was dense and hot and that its surface was also hot, if not indeed red hot. Some five years ago an English astronomer, Jeffreys, brought forward the idea that Jupiter and the other outer planets as well were ice covered. The known facts could be accounted for by assuming that Jupiter has a rocky core 57,000 miles in diameter of density three times that of water, overlying which is a layer of ice 11 000 miles thick, the latter being surrounded by an atmosphere of low density 3,500 miles in depth.

The sensitive electrical thermometer which we learned in my last radio talk was used to measure the heat from the stars, has been requisitioned also to tell us something of the surface temperatures of the planets. In a very striking way the newer theory as to the surface temperatures has been borne out, for both at Flagstaff and at Mt. Wilson the results showed that the temperature of the visible surface of Jupiter must be about 140 degrees below zero Centigrade. At this temperature nitrogen and oxygen, the main constituents of our own atmosphere, would not condense into clouds like our familiar clouds of fine water drops yet there are substances,

like carbon dioxide, for example, which would form clouds at such temperatures. It is not unreasonable to suppose, then, that some such explanation may be advanced to account for the surface markings. There is, however, much to learn yet.

XXII. The Origin of the Solar System

(December 11, 1929)

While the subject of my address may appear to be so hopelessly technical as to be beyond the understanding of ordinary mortals, I shall try to so present it that some mental picture of the process may be retained. Only a general idea of the sequence of events can be given, as so many theories, each with a grain of truth in them, have been advanced from age to age that the question is still a very unsettled one.

The problem of the origin of the solar system, while it includes the problem of the origin of the earth, might seem to be a small one in comparison with the great problem of how the millions of other suns, seen as stars, came into existence. The greatest minds of the past ages have theorized upon both these aspects of cosmogony but all I can hope to do is to outline briefly some of the principal theories relative to the more limited problem, that of the origin of the solar system.

Let us first refresh our minds with what the solar system is. The central body is what we know as the sun, a very hot body whose mass is nearly 750 times that of the combined mass of all the planets and other bodies which revolve about it. The closest planet to the sun is Mercury, requiring only 88 days to complete its orbit around it; the outermost one is Neptune, requiring 165 years to complete its extended path about the parent body. In between these limits the others find their places. Six of the eight planets have lesser bodies, known as moons or satellites, revolving about them, the total number of moons being twenty-six. A number of small planets, about 1,000, with diameters ranging from ten miles to a few hundred miles; with a few hundred comets, whose mass is prac-

tically negligible, complete the picture of the bodies comprising the solar system.

Of all the theories that have been advanced to account for the formation of the solar system possibly none have had such a wide appeal as that postulated by Laplace in 1796. He begins with a vast nebulous mass of matter, of amount equal to what we find in the system to-day, but diffused cloud-like throughout space in a great, roughly spherical formation extending beyond the orbit of the outermost planet, Neptune. As to the origin of the nebulous mass itself nothing is said. We know that such masses exist in the heavens and it is taken as a starting point.

The whole mass is supposed to have a slow motion of rotation about an axis and this speed of rotation increases as the ages go by. For the original heat of the nebula may very properly be assumed to be radiated away or dissipated into space and with such loss of heat contraction of the nebula naturally follows. It is a well established principle that when a rotating mass becomes smaller it begins to rotate faster. A particle of the outside at the equator would, as the speed increased, have a tendency to be hurled off into space, were it not held in its place by the pull, or gratitational power, of the mass. There would come a time, though, when the centrifugal force, as it is called, would be greater than the gravitational. The result, according to Laplace, would be the abandonment of the outer parts of the nebula as a separate vaporous band or ring of finely divided particles. The nebula would continue to lose heat and shrink, and once more a critical time would arrive when, to preserve the balance, another ring would be shed. In time the particles of these rings, attracted by some unusually massive ones of their number, would coalesce about them as a nucleus and form planets. Thus from time to time a ring of matter was thrown off and eventually condensed into the planets as we have them to-day. In similar manner, though on a smaller scale, originated the moons or satellites of the planets while the latter were still in a very tenuous state. This in mere outline is the theory enunciated by the French astronomer Laplace in 1796 and generally referred to as the nebular hypothesis.

The theory has been subjected to much criticism and many

objections can rightly be urged against it. I shall not weary you with them as they are too technical for a talk of this nature, but the consensus of opinion would seem to be that the objections are too great for the theory to be acceptable.

Other theories which overcome most of the objections hinted at above and are held in higher favour, postulate another disturbing sun which in some manner tore the planets from the central body. While the stars appear to the naked eye to be fixed in position relative to each other it is found from precise measures that they are moving hither and thither in space with velocities up to, or even greater than, a hundred miles per second. Now it might well happen in the course of time that some other star passed near our own in space. Such an event would be rare but it would not be beyond the bounds of probability. If the nearest star of which we have knowledge to-day were coming directly towards us at a velocity of 100 miles per second,—which happily is not the case—it would be over 8000 years before it could traverse the great distance that separates us. One can, from this crude illustration, conceive of a chance encounter or close approach of two suns in the millions of years usually assigned as the age of the system.

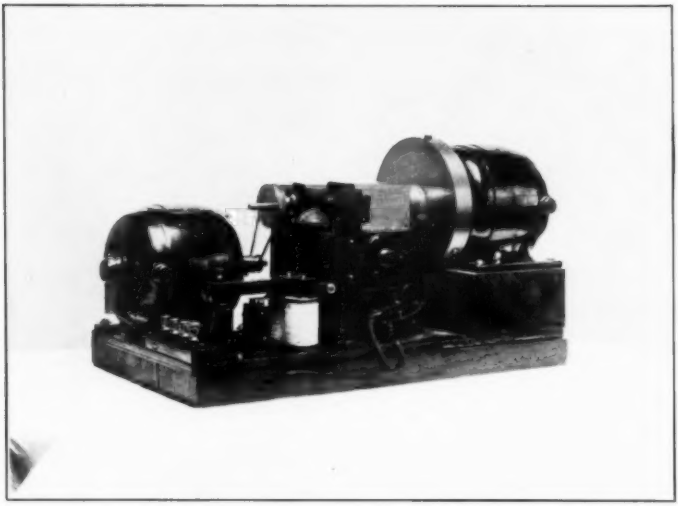
Photographs of our sun to-day reveal the fact that great fountains of gaseous matter are from time to time ejected from the interior and rise to heights of several hundred thousand miles. This is merely by way of analogy. Now what is known as the Planetesimal Theory simply states that the close approach of a wandering star would greatly accentuate this condition and great filaments of gaseous matter would be torn from the sun. At the time of this supposed disaster the sun was not quite as compact as at present and the outrushing matter would extend to great distances, comparable to the planetary distances from the sun as we know them to-day. Moreover, as the intruder moved on into space, its path curving somewhat around our own sun, there would be a tendency for the stream of matter to gravitate towards it. In this way a motion of revolution about the sun would be set up. The theory supposes that the ejected matter was in the form of gaseous particles which rapidly cooled and solidified. Masses slightly larger than the average served as nuclei around which swarms of the smaller particles collected.

The planets have thus grown from these original nuclei by the gradual accretion of the smaller bodies.

The newer or "tidal" form of the theory differs from the foregoing only in the idea that the planets must have possessed nearly their present masses from the beginning, the larger ones naturally being near the middle of the issuing stream of matter. Quite recently one astronomer has returned to the theory of an actual collision, first advanced nearly 200 years ago, and has seemed to find in it a closer representation of the facts. One can easily understand that the chance of an actual grazing collision would be infinitely small compared to the chance of a near approach of the two suns.

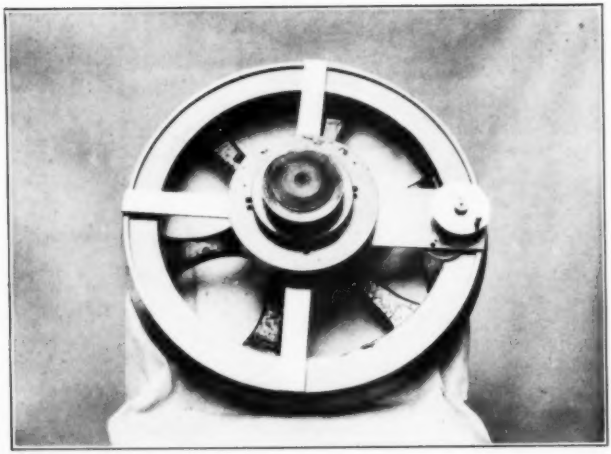
Such tide-raising or collision theories are much to be preferred to the simple rotational theory when it comes to explain the discrepancy between the plane in which the sun is rotating and the general plane of revolution of the planets about the central luminary. The time scale, moreover, seems to be more in accord with geological determinations, the great catastrophe seemingly having occurred five or ten billions of years ago.

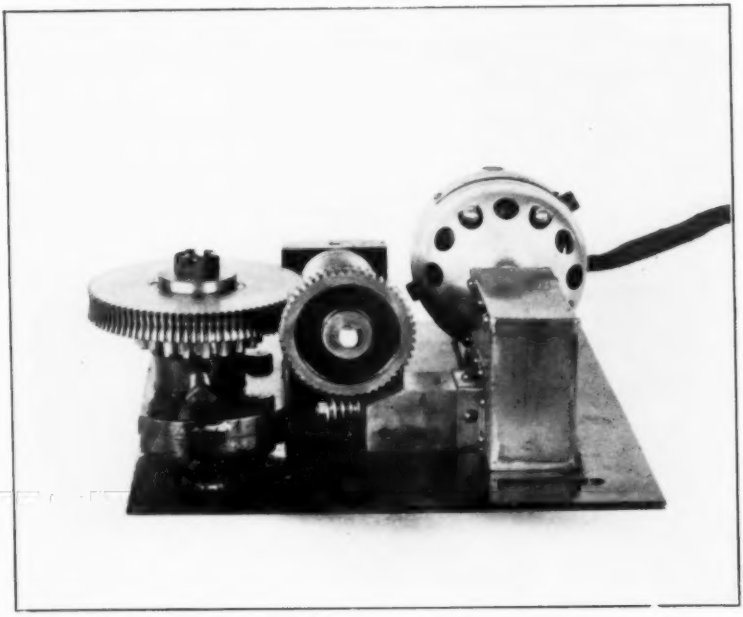
PLATE II



Above (a) is shown the electrical drive, below (b) the glass disk after it had been ground to shape and a hole drilled through the centre. The glass tool is thrown to one side.

PLATE III





Above (a) is shown the right ascension worm gear and the index arms with the drum for accurate readings. Below (b) is shown the motor and gear train for slow motion in declination.

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THE BUILDING OF A 19-INCH REFLECTING TELESCOPE

By R. K. Young

The department of Astronomy in the University of Toronto, although it has existed as a separate department for over twenty years, has no observatory for research and instruction. Courses are offered to students in general astronomy, spherical astronomy, theoretical astronomy and astrophysics. The University has had the co-operation of the small observatory of the Metrological Service of Canada for the purpose of instruction in the use of the equatorial and transit instruments. It has always been the endeavour of Dr. Chant, the head of the department, to foster a wide interest in the subject, both within and outside the University, and to emphasize the need for an observatory. It is to be hoped that the project will not be delayed much longer.

I suggested to Dr. Chant in 1926, that it would be possible to construct a telescope privately, capable of doing useful research in many lines of astronomical work, and although rather diffident to using so much time for purely mechanical work, that I would be willing to undertake the task if we could find means to house the instrument. We decided to build as large a telescope as we felt we could complete in a reasonable time and we were confirmed in this decision because we had in mind the design and construction of a much larger instrument. The first-hand information obtained in building the smaller telescope would be extremely valuable in crystallizing our conceptions of what would be required in a bigger one.

The present article is a description of the design and construction of a 19-inch telescope. It is published here because we think it should not be beyond the powers of the ambitious amateur to construct a similar or better one. It has been completed with the aid of a very modest workshop and occasional outside help for such work as could not be done on a lathe. It has taken about two years to construct, using only spare time in holidays and such time in the evenings and week-ends as available outside of university duties. The cost of the material and incidentals were roughly as follows:

1. Optical parts purchased, including plane mirror, finder lenses, eye pieces and disk for large mirror	$346.00
2. Outside work done, gear cutting, patterns, etc.	625.00
3. Castings, motors, bearings, incidentals.	529.00
Total.	$1,500.00

There are some very excellent works published on the grinding and polishing of mirrors, among which may be mentioned, *The Reflecting Telescope* by George W. Ritchey, in the Smithsonian Contributions to Knowledge, being part of Volume XXXIV; *The Amateur's Telescope*, by the Rev. W. F. A. Ellison; *Amateur Telescope Making*, by the Scientific American Publishing Co. We particularly recommend the last reference for the guidance of the beginner. The descriptions of the mounting in these books are not so satisfactory as for the mirror, and the ordinary amateur is inclined to mount his telescope in a very simple and inexpensive style. There is no doubt that a great deal of pleasure and profit may be obtained with even a crude mounting but labour spent on mounting will be amply repaid in the pleasure of using the telescope, more especially if the telescope is to be used for useful research work. As additional references, the beginner might read the very excellent description of the 72-inch reflecting telescope of Victoria, B.C., published as the first number of the Publications of the Dominion Astrophysical Observatory, and a book entitled *The Telescope*, by Louis Bell, published by the McGraw-Hill Book Company.

The Mirror

The main mirror consists of a piece of pyrex glass four inches thick and 19½ inches in diameter, which we received from the Corning Glass Works in March, 1926. The simplest material for the amateur to select for small mirrors is ordinary plate glass, the thickness being from 1/5 to 1/10 the diameter. The beginner might try a plate of chromium steel to advantage if he is of an experimental turn. This material will take a high polish and retain it for many years and requires no silvering. It has not

however been used and would be an experiment. For mirrors more than twelve inches in diameter steel is rather heavy, and ordinary plate glass is not of good enough quality even if it could be obtained of the required thickness. What is desired is a substance with small expansion with heat and of great rigidity. Quartz disks possess these qualities to an admirable degree but at the time of beginning the 19-inch they were in the experimental stage and could not be obtained more than 12 inches in diameter. They are available in much larger sizes now. Pyrex glass, as is well known, was developed on account of its small coefficient of expansion with heat and it appeared to me to be the best material. It has the drawback, that it is very difficult to melt and consequently difficult to free from bubbles in the pouring. Large disks are usually much marred by these defects. The disk we obtained was rather bad but, as no bubbles of any size would come near the finished surface, I decided to use it.

The disk as it came to me from the makers was about half-an-inch thicker at one edge than at the other and the sides were much seamed. The first task was to shape the disk. I constructed a fairly large grinding table with a rotating turntable in the centre. In order to true up the sides of the disk, I placed a brass band about four inches wide and one sixteenth of an inch thick around the glass and fed carborundum and water to it as the disk rotated. It proved a very noisy affair but reasonably effective. The turntable is shown on Plate II(*b*), where the disk is also shown after it had been trued and a hole drilled through the centre. The turntable was operated by a system of belts and pulleys beneath the table which are not shown in the photograph. The motive power was furnished from the workshop motor. An iron tool about twelve inches in diameter and three-quarters of an inch thick was used to grind the top flat and parallel with the bottom. By bearing down when the tool was resting on the high side, the disk was gradually trued up. The whole process took quite a little muscular effort but not a great deal of skill or time. About two weeks after the reception of the glass it was brought to shape, a comparatively short time compared to the tedious but interesting months of labour it took to figure the surface.

The final surface of a reflecting telescope mirror is in the form

of a parabola, to which the equation in Cartesian geometry is, $y^2=2Rx$. The focal length of the mirror is $R/2$. In Figure 1, y is the distance of any point, such as P, from the axis AD; and x,

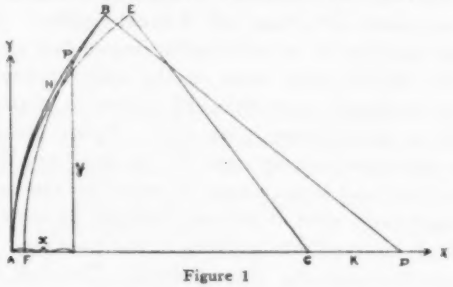

Figure 1

the depth of the mirror below the chord joining two points on the surface, each at a distance y from the axis. In the present case, the focal length was to be 125 inches so that the equation to the final parabola would be $y^2=500x$. The depth of the curve at various distances from the centre is readily computed to be that shown in Table I.

TABLE I

Distance from axis	Depth	Distance from axis	Depth
1 in.	.002 in.	6 in.	.072 in.
2 "	.008 "	7 "	.098 "
3 "	.018 "	8 "	.128 "
4 "	.032 "	9 "	.162 "
5 "	.050 "	9.5 "	.180 "

The beginner may not realize how nearly the surface approximates to a sphere or, what amounts to the same thing, how closely the curve *BPHA* in Figure 1, which is the parabola, can be made to fit a circular arc. In order to show this, imagine a circle described with centre at C and radius AC, equal to 250 inches. The equation to this circle is

$$(x-250)^2+y^2=250^2,$$

or

$$x=250-\sqrt{250^2-y^2};$$

and it may be readily shown that for any given y, the difference

between the x for the sphere and the x for the parabola is, to a very close degree of approximation, $8 \times 10^{-9} y^4$ inches. For the outside of the mirror, where $y = 9\frac{1}{2}$ inches, the difference equals BE and can be computed to be 0.000,006,5 inches. The small difference between the sphere and parabola is quite below any ordinary method of measurement and the first step in grinding the mirror is to obtain the sphere. The small amount of glass which has to be removed afterwards is polished away by the so-called process of figuring.

The twelve inch castiron tool was used to hollow out the disk until micrometer measures indicated that the depths shown in Table I were obtained. All this work was done with coarse carborundum, grade No. 40, and the grinding stopped a little short of the computed depths, leaving the last few thousandths of an inch to be removed by fine grinding. A glass tool was then substituted for the iron one. This tool is shown in Plate II*b*, which also shows the manner of operating the tool on the glass. A long arm was pivoted at one edge of the grinding table and the glass tool fastened near its centre. The exact position of the tool could be adjusted by means of various holes in this arm, and at the same time it was left free to rotate. The operator, holding the end of the lever arm, could move the tool latterly over the mirror with any desired stroke. The details of the process of fine grinding and obtaining a surface ready to polish is fully described in the references quoted, and I shall not describe them here, further than to say that this part of the work was very satisfactory and the desired result easily obtained and that in a comparatively short time the disk was ready for polishing.

I followed the procedure described by Ritchey in polishing, using resin and turpentine for forming the tool, and rouge as the polishing agent. At first I used a built up tool from pieces of wood reinforced on the back by strips of angle iron and had considerable difficulty with the tool warping. Eventually I abandoned this tool and made an aluminum one, which was much more satisfactory and the surface brought to a satisfactory polish.

As soon as the mirror was polished I tested it to find out how nearly I had succeeded in obtaining a spherical surface.

Figure 2 shows the apparatus for measuring the radius of curva-

ture of the various parts of the mirror. The method of grinding ensures the mirror being a true figure of revolution and so it is necessary to test zones at various distances from the centre only. Light from the 24 c.p., 12 volt, light *L* is concentrated on a small piece of opal glass in front of a small pin-hole at *P*. Light from this source, which is placed near the centre of curvature of the mirror, is returned to the totally reflecting prism at *B* and bent upward so that the eye placed at *E* sees the whole mirror flooded with light. By moving the apparatus forward or backward by means of the screw on the tail stock of the lathe on which the light source was mounted, and sliding a safety razor blade back and forth over the top of the box, between the eye and the beam, the

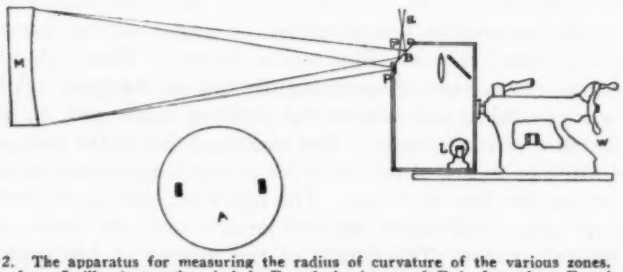

Fig 2. The apparatus for measuring the radius of curvature of the various zones. Light from L illuminates the pin-hole P and the image of P is formed at E. A knife-edge slides across the top of the box and determines the exact position of the focus.

position of the focus could be determined. One revolution of the wheel *w* moved the source of light 1/10 of an inch and the circumference being divided into ten equal parts estimations could be made to the thousandth part of an inch. In practice the mirror was covered by means of masks such as that shown at *A*, and the radius of curvature of the various zones on the mirror determined.

As indicated before, the sphere is changed into a paraboloid of revolution by removing a very small amount of glass, an amount which could be polished away in a very short time, provided it could be done correctly. There are three ways to effect the figuring, viz, by removing glass from the outside, by removing glass from the centre, or some from the outside and some from the centre. To see this examine Figure 1. The parabola is the curve *BPHA*. Let

the co-ordinates of the point B be x_0, y_0. The equation to the normal at the point B is

$$(y-y_0)R+(x-x_0)y_0=0,$$

and this cuts the axis Ax in the point $x=x_0+R$, or D. With D as centre and BD as radius, describe the arc of the circle BF, cutting the axis Ax in F. The distance AF is given by

$$AF=x_0+R-(R^2+y_0^2)^{\frac{1}{2}}.$$

The sphere may be changed into the parabola by removing the cap of glass BAF and the focal length obtained will be $R/2$. In order to obtain this we must start with a sphere of radius

$$x_0+R \text{ or } R+y_0^2/2R.$$

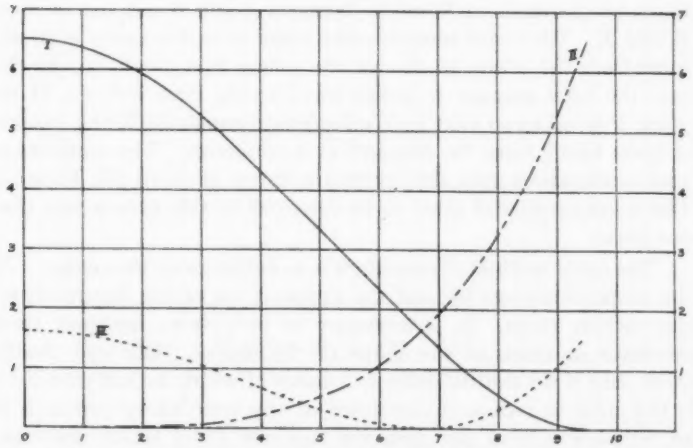

Fig. 3. Curves showing the amount of glass which must be polished away to parabolize a sphere. Ordinates are expressed in hundred-thousandths of an inch. Abscissae are distances from the centre of the disk. I, polishing from the centre. II, polishing from the edge. III, polishing some from the centre and some from the edge.

The amount which must be removed is shown by the full curve in Figure 3. It may be shown that the total mass of glass which must be removed is given by

$$M=\frac{\pi y_0^6 \rho}{24R^3},$$

where ρ is the density. For a glass of specific gravity 2.5 this

amounts to the surprisingly small quantity 0.25 grams or 3.9 grains. In this case the polishing is done at the centre.

With C as centre and CA as radius, describe the arc of the circle AE with a radius equal to R. We could change the sphere into the parabola by removing the cap of glass ABE, and in this case we would polish away the outer edge. The amount of glass which would have to be removed at various distances from the centre is shown in curve II, Figure 3, and the total mass of glass which would have to be polished away is just the same as before.

Take a point P on the parabola and draw the normal. The normal will cut the axis in some point K lying between C and D. If we describe a circle with K as centre and KP as radius, it will touch the parabola at P and lie between A and F and also between B and E. We could remove some glass from the outer edge and some from the centre to change the sphere to a parabola. In this case the total amount to polish away is less than before. If the point P is taken so that its x co-ordinate equals $x_0/2$, the amount of glass which must be removed is a minimum. The amounts at various distances from the centre are shown in curve III, Figure 3. The total amount of glass to be removed in this case is less than one grain.

The usual method of procedure is to polish away the centre. As the work progresses we test the radius of curvature frequently for the various zones. It is necessary to be able to interpret these measures in terms of the shape of the mirror. One can readily show that if we test the mirror in zones of width Δs and that if ΔF is the error in radius of curvature of any zone whose centre is at an ordinate y from the axis, the distance D by which the inner edge of this zone is high or low, beyond that of the contiguous zone farther out is given by

$$D = \frac{\Delta s \, \Delta F \, y}{R^2}.$$

From this formula we may construct the actual shape of the surface in relation to the paraboloid required.

In order to illustrate the use of this formula I give a set of readings made in the earlier experimental stages, together with the curve representing the shape of the mirror.

TABLE II

Zone	Measured Focus	Parabolic Focus	ΔF	$\frac{\Delta F \Delta sy}{R^2 10^{-7}}$
9½-8½	.000	000	000	000
8½-7½	−.048	−034	−014	+17.9
7½-6½	−.048	−064	+016	+17.9
6½-5½	−.082	−090	+008	+ 7.8
5½-4½	−.090	−112	+022	+17.6
4½-3½	−.120	−130	+008	+ 5.0
3½-2½	−.128	−144	+016	+ 7.8
2½-1½	−.140	−154	+014	+ 4.4

The columns in Table II are consecutively, (1) the limits of the zone measured, each zone being one inch wide. (2) The measured

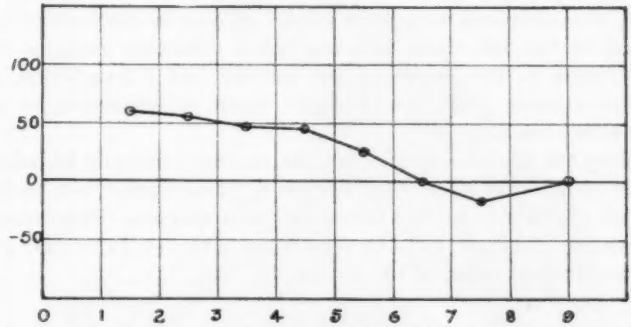

Fig. 4. The condition of the surface shortly after starting parabolizing. The ordinates are expressed in ten millionths of an inch above or below the required surface and abscissae are distances in inches from the centre of the mirror.

position of the focus in inches, the outer zone being the starting point from which the others are measured. (3) The calculated foci for a parabolic mirror, the numbers in this column being obtained from Table I, because the aberration at the centre of curvature for any zone equals the depth of the mirror below that point when tested by moving both the knife edge and source of light. (4) The amount the measured aberration differs from the computed. (5) The error in the surface expressed in ten millionths of an inch. The first and last columns are plotted as a graph in Figure 4. At that time there was a low spot about 7½ inches from the centre.

I used local polishes almost entirely to produce the desired

figure, smoothing up the surface from time to time with a full-size or two-thirds-size polisher. I shall not describe any of the methods used in making the polishing tools as these are treated very fully in the references given, but it may be of service to someone if I emphasize a few points. Before starting to polish be sure that you know the shape of the mirror. This may involve repeated measures, with precautions being taken that the room is at a uniform temperature and the air steady. See that the tool fits the glass. This is especially necessary with the large polishers. I usually allowed the large polishers to *cold press* for several hours before using. Try to get a room for testing where the air is steady. I had some difficulty in this regard. The workshop was in a basement and during the summer months, when there was no furnace going, the conditions were quite good. As soon as the furnace was started in the fall there was too much difference between the temperature in the basement and outside and I found that air currents coming from the windows made it impossible to get satisfactory readings.

When the figure seemed to be right, as nearly as could be judged by the visual knife-edge tests, I made a photographic test by the method described in the Dominion Astrophysical Observatory Publications, Volume I. The results are given in Table III, and express the final shape of the mirror.

TABLE III

Zone	Measured aberration	Computed aberration	O-C	Equivalent O-C at Focus
9	8.26	8.22	+.04	+.01
8½	7.50	7.34	+.26	+.06
7½	5.35	5.71	−.36	−.09
6½	4.05	4.29	−.24	−.06
5½	3.15	3.07	+.08	+.02
4½	1.59	2.05	−.48	−.12
3½	1.15	1.24	−.09	−.02
2½	1.26	0.63	+.63	+.16

The aberrations are expressed in mm. The centre zone is covered up by the secondary mirror which is 5 inches in diameter. Outside of this zone the greatest departure is in the 7½- and 8½-inch zones, but all are fairly small. One can compute from these numbers

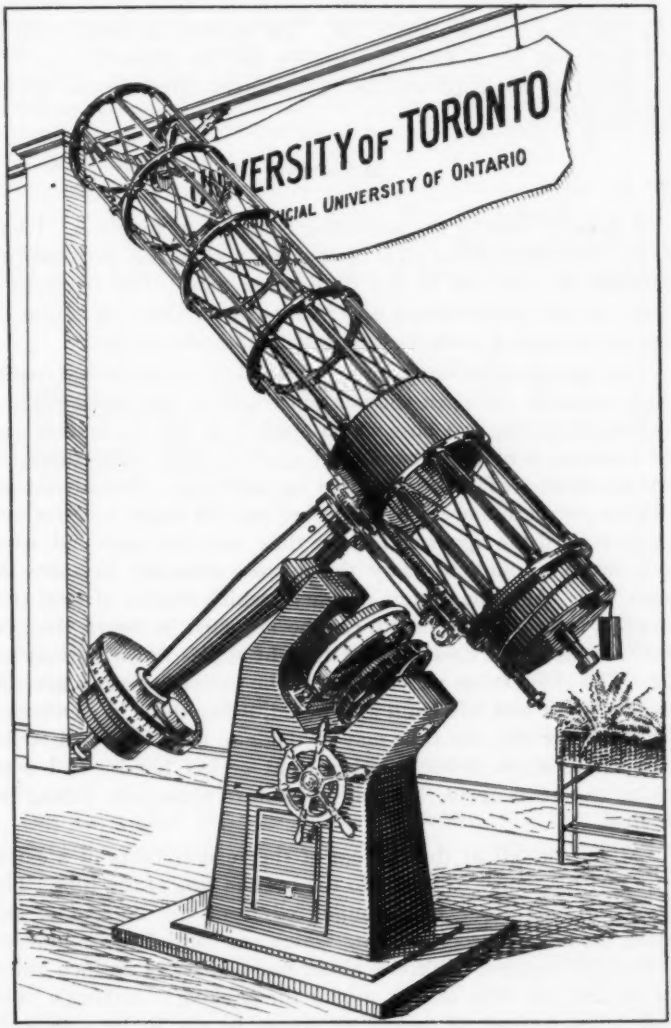

Figure 5

the angular diameter of the mean circle of confusion of the image of a star, and it comes out 0″.16. The theoretical diameter of the diffusion disk for a 19-inch telescope due to diffraction is 0″.24 so that the telescope should theoretically give almost perfect definition.

Mounting

A general view of the mounting is shown in Figure 5. I have chosen the conventional form of equatorial mounting with the tube mounted on one end of the declination axis. The telescope is meant to rest on a cement pier rising two or three feet from the floor so as to give room to walk underneath the mirror.

The tube is of the open type. It consists of the central casting which supports the open tubular construction, and on one side of the central casting is a boss which holds it to the declination axis. The framework of the tube is built up from light steel tubing in sections which are fastened together by steel rings. The advantages of this construction are that the tubes may be made progressively lighter toward the upper end of the tube, and the lower end, when made heavy enough to carry the mirror, naturally balances the longer end. Also the system of braces, which consist of steel rods threaded right and left hand, can be adjusted to bring the geometrical axis of the tube exactly at right angles to the declination axis. The short tubes which connect the various sections are also threaded right and left hand and by adjusting these in connection with the brace rods the tube may be made to bend in any direction or to rotate screw fashion, either right or left hand. If I were making the tube again, I would substitute aluminum tubing for the steel.

The mirror cell at the bottom of the tube consists of a single casting with a flange to bolt it to the bottom ring of the tube. The mirror rests on three disks supported from the bottom of the casting on ball-and-socket joints which can be raised or lowered to effect collimation. There is about one-quarter of an inch clearance around the edge of the mirror for packing. Although very simple, this method of mounting seems to me to be sufficient. The complicated system of levers and counterweights is quite un-

necessary unless the mirror is very thin. The mirror is ground, polished, and figured on a simple turn-table, placed on its edge for testing, without any special support. Its position and use in the telescope tube makes no greater demand on its rigidity than the conditions of testing, and if the mirror shows a good figure in the laboratory tests it should not be necessary to introduce elaborate methods of supoort in the telescope.

The secondary mirror at the top of the tube is a five-inch flat made by J. W. Fecker of Pittsburgh. It is supported in a light aluminum casting carried by four strips of saw-steel about three inches wide which reach to the sides of the tube. The supports

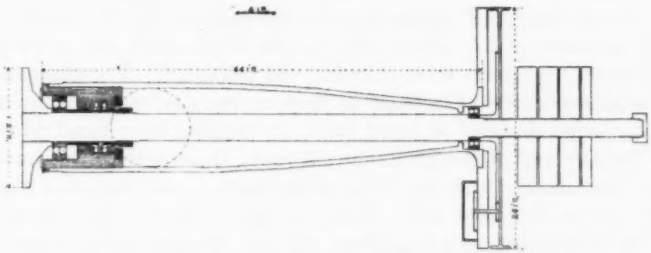

Fig. 6. A longitudinal section through the declination axis and housing.

for these strips on the tube can be adjusted for focus and the mirror cell can be rotated to bring the image out to the edge of the tube in any position. The plate carrying the eye pieces can be fastened at either side of the tube, toward the pier or away from it as most convenient. A second mirror cell can replace the Newtonian mirror when the telescope is to be used in the Cassegrain form.

The declination axis and housing is shown in Figure 6. The axis proper consists of a cold rolled shafting three inches in diameter and the housing is a moulded casting carrying at its inner end the aligning and double-thrust bearings shown in the figure, and at its outer end a simple aligning bearing. These bearings are S.K.F. and the tube moves very freely but without perceptible play. When the tube is balanced, about two ounces applied to the upper end of the tube will start it moving. The main part of the counterweight for the tube, consisting of a large castiron flange, is fastened

to the declination housing, and four castiron weights threaded on the end of the declination axis proper serve for adjustment. The declination circle consists of a bronze wheel, two feet in diameter and 2½ inches face, rigidly fastened to the declination axis. It is divided into single degrees. In order to be able to read the declination more accurately than this when setting on a star, I introduced the same kind of gear system as used in the 72-inch telescope at Victoria, B.C. The declination circle carries a gear wheel of 270 teeth 18 D.P. and this engages by a train of gears to a small drum carried by the counterweight flange. This small drum is a very light aluminum wheel about seven inches in diameter and makes one revolution for a motion of the telescope in declination of ten degrees. Estimation of declination can be made to single minutes of arc when viewing the drum from the position the observer occupies when moving the telescope. The clamp in declination consists of a band of iron on the declination housing which can be clamped or freed from the housing by a hand wheel near the eye end of the finder on the tube. Fastened to this band is an arm about 18 inches long which has a small arc of a gear wheel cut in its outer end. This engages with the slow motion gear in declination shown in Plate III(*b*). A hand switch carried by the observer can be made to operate the declination motor in either direction for the purpose of fine adjustment. When running at full speed this motor will move the telescope about one degree in four minutes of time. By giving the switch a quick tap the tube can be moved as small an amount as one-tenth of a second of arc.

The polar axis is made from a piece of 4-inch cold rolled shaft and carries at its upper end a flange which bolts it to the declination housing. A cross section through the polar axis is shown in Figure 7. This section shows in order the various wheels carried on the polar axis. Starting from the bottom there is first the fast-motion hour circle wheel, 108 teeth, 6 D.P., which engages a pinion and communicates with the hand wheel shown on the side of the pier in Figure 5. This wheel is rigidly fastened to the axis and a flange on its edge is graduated to indicate the hour angle of the telescope at any time. Above the hour circle wheel is the wheel for the clock drive. This wheel consists of a castiron centre with a

bronze ring shrunk on its outer edge, the bronze ring forming the worm gear of the drive, 360 teeth, 18 D.P. It turns freely on the axis but can be clamped to the axis by the single-disk clutch which is shown immediately above it. On its lower edge it carries a sidereal circle which can be adjusted at the beginning of the night to read right ascensions directly. The sidereal circle is graduated to four minutes and in order to set more accurately there is a set

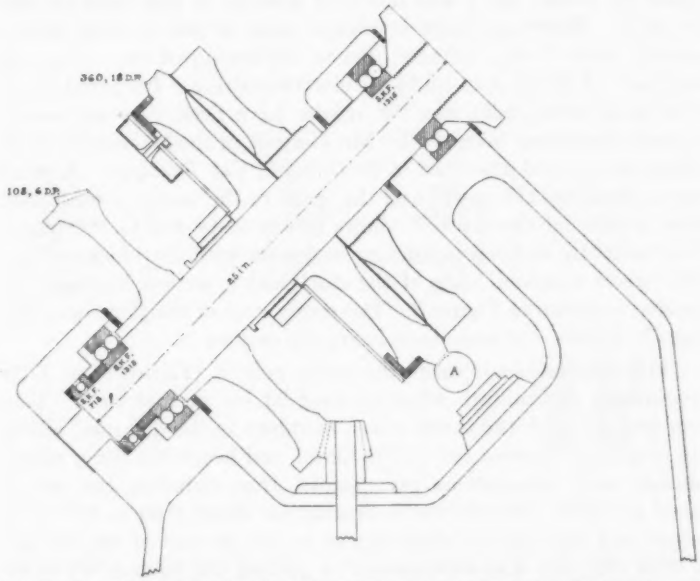

Fig. 7. A section through the polar axis and the top part of the pier, showing the gearing and the various driving wheels and clamp in right ascension.

of gears which engage with the small drum shown on the index arm in Plate III(*a*). The small drum makes one revolution in ten minutes. The operator standing beside the pier turns the hand wheel until the R.A. reading is correct to the nearest 5 seconds and then clamps in the clock drive by the single-disk clutch. The worm screw is indicated at *A* in Figure 7. It has three degrees of freedom, not shown on the cut, which make it possible to obtain the proper mesh with the worm gear. The worm gear and sidereal

circle are also shown in Plate III(*a*). In this plate a temporary axis has been inserted in order to carry the index arms and the small drum for fine reading in right ascension.

The Clock

The astronomical department possessed a gravity driven clock made by Cooke but I was doubtful whether it was large enough to serve. Moreover there is always more or less trouble with a gravity drive in this climate, due to thickening of the oil in cold weather. I decided to build an electrical drive. I wanted to do this as an experiment and the results have been very successful. I chose the system invented by Mr. Gerrish, of the Harvard College Observatory, and described in Bell's book, *The Telescope*. A small motor furnishes the power and the speed of the motor is controlled from a sidereal clock which allows power to be fed to the motor intermittently to keep it running in unison with the clock. Plate II(*a*) gives a general view of the clock and a section through the gearing is shown in Figure 8. The entire cost of the parts was less than 75 dollars, the main item being the motors.

The driving motor turns the worm gear *A* (Figure 8) at 1725 revolutions per minute when running at its normal rate. This gear engages with the timer wheel, as shown in the diagram, which interrupts the current fed to the motor and keeps the timer wheel running sixty revolutions per minute, thus reducing the motor speed to 1600. The current is flowing for about 0.60 to 0.75 of a second and the balance wheel carries on for the rest of the second. A little difficulty was experienced in getting the balance wheel to run smoothly, but by inserting small weights around its edge, as in the balance wheel of a watch, it was finally adjusted so that no vibration could be felt. The electrical circuit and the manner in which it operates are fully described in Dr. Bell's book.

The driving motor communicates through a differential train of gears to the driving shaft. The normal rate of rotation of the driving shaft is ten revolutions per minute when the differential gear is held; and in order to provide slow motion and guiding motion in right ascension I introduced a second motor to operate the differential gear. The second motor makes 1200 revolutions

per minute and when running it adds or subtracts from the rate of rotation of the driving shaft according to the direction of its rotation. When running at full speed and subtracting its rate from the clock drive, the driving shaft has a slow rotation forward and when running at full speed in the opposite direction, the driving shaft turns at nearly double its normal rate. The same hand switch which operates the declination slow motion operates this

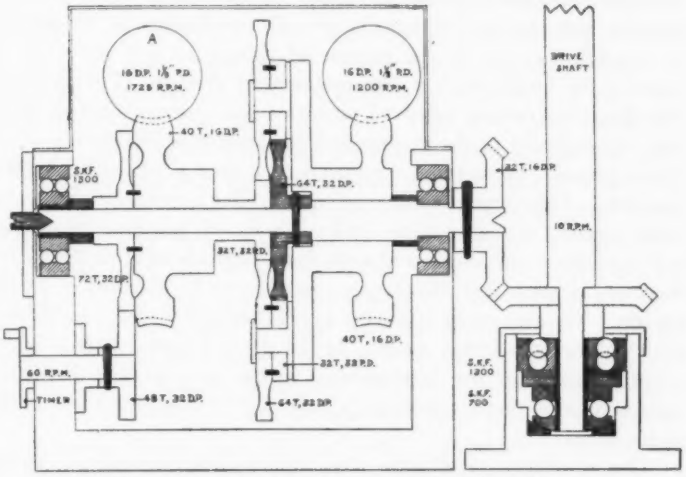

Fig. 8. A section through the electrical clock gearing.

motor also, so that the observer by pressing the suitable button controls the telescope in right ascension and in declination. A sharp tap on the right ascension button can make the telescope move as small an amount as one one-hundredth of a second of time. I have not had the opportunity of testing the following of the clock on the stars but have had it running in unison with the sidereal clock which it follows perfectly. We hope soon to find a suitable place to house the telescope so that it may be used for instruction in the university and for research work.

THE MATHEMATICAL PRELUDE TO THE THEORY OF RELATIVITY

By Alfred T. De Lury

The Theory of Relativity of Einstein, still controverted and still awaiting confirmation in certain essential particulars, would seem to constitute an epoch-making advance. As the names of Copernicus, Newton and Darwin are associated with revolutions in the attitude of the human mind to the scheme of things, so will the name of Einstein be linked with a like momentous change. To his mind, brooding over certain unsolved problems and seeking some principle into which would fit the various and challenging achievements of the newer physics, there came the vision of a theory adequate to these demands. This theory, concerned with subtler concepts than was the older theory, and aiming to unify a body of physical knowledge and conjecture vast compared with that comprehended in the earlier theories, is such that the larger significance is necessarily to the initiate. Yet aspects of it have a general appeal and are modifying the thinking of a larger circle. In the present paper there is given a brief account of the developments in mathematics and in mathematical outlook that played a large part in the evolution of the theory of Einstein.

The geometry of Euclid—the highest achievement of Greek science—as interpreted through the centuries down to almost our own day, confirmed the natural conviction that perceptual space is uniform, infinite in extent, and in a sense absolute. This science has for base certain postulates that have their roots in experience. From the first, however, there was felt to be a defect—not an error—in the treatment of parallel lines and the implications as to the infinitude of space. Eucild's postulate-bearing on this requires as an immediate consequence that the angle-sum of a triangle is two right-angles. This property of the triangle, with all that flows from it, was accepted as inherent to space, but there were ever-renewed attempts to place the theory on a more satisfactory foundation—all without direct success. In the early nineteenth century it occurred to

two geometers the Russian Lobatchevsky and the Hungarian Bolyai to relinquish Euclid's postulate regarding parallel lines and to admit that there might be drawn through a point many straight lines not meeting a given straight line. Retaining the other postulates, they developed a geometry—consistent and therefore *true*—in which the angle-sum of a triangle is less than two right angles, and is different, in general, in different triangles, while similar figures, differing in size, cannot exist. In this—newer geometry—non-Euclidean—the Euclidean may be said to be included as a particular case or better—a limiting case. The formulæ for application to the problems of space are less simple, but can be attuned so as to be in accord with such space-experience as is possible. The philosophic result was the realization of the fact that a system of geometry is a creation of the mind, and that the space is conceptual. This thought might as well have come from the consideration of Euclid's geometry alone. Every geometry should admit application to actual space-problems and should not fly in the face of the fact, yet it should not be assumed that the conceptual space implied in it is a replica of actuality.

Later, under a new impulse, another postulate of Euclid was relinquished—it too having a relation to the infinitude of space—and a consistent geometry established. In this there were no parallels, and the angle-sum of a triangle exceeded two-right angles, different triangles in general having a different angle-sum. This geometry is essentially that of the geometry on the surface of a sphere, the arcs of great circles corresponding to the straight line.

In the meantime the study of geometry was being directed along the line of the general from another quite different point of view. The methods were those of analytical geometry and the infinitesimal calculus. Gauss, professor of mathematics at Göttingen and in charge of the state surveys, naturally reflected much on the geometry and trigonometry of the earth's surface, and was led to a study of lines and figures on a general surface. The primary lines on a surface, the analogues of the straight-lines on a plane, are those called geodesic lines—the geodesic being the unique line, the line of least length, the most direct route from one point to another along the surface. In particular he obtained the expression for the line-element, and made precise the idea of the curvature of a surface.

His papers on this and related subjects opened up a new and fruitful field in which many were to find an impulse and an inspiration. An important result was a certain measure of emancipation from the traditional attitude to space and its problems.

Among those who were influenced by the work of Gauss, perhaps, the most outstanding is Riemann. In a memorable paper on the Foundations of Geometry, acknowledging his indebtedness to Gauss, he regards space, as ordinarily conceived, as a three-dimensional manifoldness admitting generalization in the direction of the number of dimensions. Accepting then a n-dimensional space, he proceeds to apply the Gaussian conception of curvature to it, and to prepare the development of the geometry known as Riemannian. In a space of three dimensions, this is the geometry previously referred to as analogous to the geometry of the sphere.

In the science of dynamics, or better perhaps, of the motion of bodies in space, it is a question of a four-fold manifoldness, the three dimensions of space as ordiniarily understood, and the one dimension of time. While it had been a mode of speech to refer to a four dimensional space being involved in this science, it was Minkowski, working along the lines of Riemann's investigations, who gave a new and precise meaning to this statement, and opened up a new vista to the mathematical physicist.

While it could be said that there is scarcely any mathematical discipline without contact with the new theory, and while certain special mathematical inventions counted for much in the development of Einstein's theory, it would not be possible here to do more than to mention these facts. It has been thought to be sufficient to indicate briefly how through the evolution of the geometry of space the mind of man was made ready for a new and comprehensive theory.

University of Toronto,

NEWS AND COMMENTS

It is with great regret that we report the death on December 25 of Dr. Ralph Hamilton Curtiss, Professor of Astronomy and Director of the Observatories, University of Michigan. His untimely death, having scarcely reached the age of fifty years, was announced at the recent meeting of the American Astronomical Society at Harvard College Observatory, amid many expressions of sorrow for the loss of a prominent fellow-member and one who had made such a distinguished record in astronomy.

The American Astronomical Society has just commenced an Appointment Service, the Council having approved the proposal to invite an exchange of information concerning vacancies and candidates. The Secretary of the Society, Dr. Raymond S. Dugan, Princeton Observatory, states in his circular to the members of the Society, that he will gladly receive and place on file any information relating to this and answer inquiries with any suitable information that may be on file. "While the number of positions in astronomy and the number of people available for such positions is still small relative to most other sciences, there is often some difficulty in finding the right man for the right position. On the one hand there are vacancies to be filled; on the other, there are men and women, in particular those just finishing their graduate work, who have to be placed". This should be a valuable service to astronomers, and any readers who have suitable information should communicate with Professor Dugan, Princeton, N.J.

The Canadian Geographical Society held its first meeting at Ottawa, January 17. The inaugural address was delivered by Sir Francis Younghusband, famous explorer and past President of the Royal Geographical Society, the subject being, "The British Mission into Tibet". The Society will publish a magazine similar to the Geographic Journal and National Geographic magazines. The annual fees for Ordinary Members is three dollars, and for Fellows of the Society, four dollars.

The Royal Astronomical Society has bestowed its medal on Dr. J. S. Plaskett, Director of the Dominion Astrophysical Observatory, Victoria, B.C., for "valuable observations of stellar radial velocities and important conclusions derived from these observations". He has accepted the invitation of the Society to deliver the George Darwin Lecture for 1930.

Professor C. A. Chant, University of Toronto, is collecting information about a fireball seen at 5.47 or 5.48 a.m., January 3, 1930. Reports from Lindsay, Thornhill, London, Port Dover, all say it was a little west of south. He is anxious to learn if anyone in the United States saw it in the north. It was especially brilliant and slow moving, and a light trail persisted for minutes afterwards. Any readers who have information on this fireball should send it in to Dr. Chant.

The summer meeting of the American Astronomical Society will be held in the Adler Planetarium and Astronomical Museum Chicago.

REDEL.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

QUERIES

1. I have been looking at the beautiful plates issued in the JOURNAL thus far for 1929 and should like to have some framed. Have you these (and perhaps other) plates of celestial objects printed separately?

2. Could you advise me if Sir James Jeans' book, *The Universe Around Us*, is suitable for amateurs?

3. What telescope is suitable for a beginner in studying the stars, planets, etc.?

4. Would it be better to purchase such a telescope or to build one's own, using for instruction (say) *Amateur Telescope Making*?—John H. Bartlett, Duncan, B.C.

ANSWERS

1. Fine photographic prints can be purchased at very reasonable prices and it would be better to frame them. Write for cata-

logues to Yerkes Observatory, Williams Bay, Wis.; and Mount Wilson Observatory, Pasadena, Cal.

2. Quite suitable and very readable.

3. A 3-inch refractor is a very good telescope for a beginner, though smaller ones reveal many wonderful objects.

4. If you have the taste for mechanical work, together with some patience, nothing will give more pleasure than to make and use your own instrument.

QUERY

Is there a printed list of the books in the Society's library available for members? I have a 3-inch refracting telescope made for me about 25 years ago by W. & D. Mogey, then of Bayonne, N. J., now of Plainfield, N. J. I have made an equatorial mounting and am now trying to get, or make, reading circles for it.—H. L. Moyer 94½ Queenston St., St. Catharines, Ont.

ANSWER

There is not a printed catalogue. In the Library are many books on various branches of astronomy. You are to be congratulated on making the mounting for your 3-inch, and I hope you may succeed in producing the graduated circles.

CAPTAIN JOHN GRICE'S RECOLLECTIONS

An interesting letter was recently received from Capt. John Grice, a retired sea captain living at Tofino, Clayoquot Sound, on the west coast of Vancouver Island, B.C. He is a charter member of the Victoria Centre and maintains an active interest in the Society, although living at a great distance from Victoria. Part of his letter, which is dated November 23, 1929, and was addressed to the president of the Victoria Centre, follows:

Making some repairs to my old home caused a rearrangement of a number of books which brought to my notice a book I feel sure will be well known to you, "Heroes of Science: Astronomers" by E. J. C. Morton. It recalled to my remembrance the contents of that volume, having had them drilled into me by the author himself when he was the Lecturer on Astronomy at the College of Physical Science in Newcastle-on-Tyne in connection with the Cambridge University Extension. The history and characters of these early workers in making a firm and secure foundation for the building of the science of astronomy and the praise he bestows on all of them are fairly

well recorded in his book, but the admiration he had for Kepler almost amounted to hero worship. His words and the scene are indelibly imprinted on my memory and I can imagine I hear him declaring from the platform, "John Kepler was the honestest man that ever lived and the world might still have been groping in ignorance and in doubt had it not been for Kepler's stainless soul." What a host of memories Professor Morton's book awakened in my mind. We had amongst our text books for the lectures Sir George B. Airy's "Lectures on Astronomy," which was very familiar to me,—in fact I had some years before descended the coal mine at Harton and saw the very place where the Astronomer Royal, by means of pendulum vibrations, weighed the earth." Professor Morton also delivered the same course of lectures at Backworth, in Northumberland, a coal mining village and the class was entirely composed of bona fide working class students. The cost in connection with the lectures was paid by the owners of the coal mine. A Quaker family named Richardson, the mining village and the owners of the mine were well known to me. All these circumstances conjointly caused the lecturer and myself to be on very friendly terms and near the finish of the lectures, in speaking of the students at Backworth, he spoke of them in the very highest form of praise and good will. After the lectures were finished I accompanied him to address some of Archdeacon Edward Prest's students at St. Mary Church at Gateshead.

The above is a sketch from memory of what was enacted more than fifty years ago and fifty years is a large slice of a man's life. I would be delighted to know if any other member of the Victoria Centre attended Professor Morton's lectures, not particularly at Newcastle-on-Tyne but at any other place.

A Brilliant Fireball

At about 5.47 a.m., January 3, 1930, a very bright fireball was seen by a considerable number of people in Toronto and in places in the southwestern part of Ontario. It was also observed at Lindsay and possibly near Parry Sound. From Toronto it appeared in the southwest. The present writer asked the Toronto newspapers to call for reports which they courteously did. Over fifty letters have been received, and to analyse them will require a month or more. A report will be printed later. In the meantime if this should meet the eye of anyone beyond the boundary of Ontario who saw the phenomenon, the writer would be pleased to hear from him.

C. A. C.

MEETINGS OF THE SOCIETY

AT TORONTO

Nov. 19—The meeting was held in the Physics Building of the University of Toronto at 8 p.m., Mr. J. R. Collins in the chair.

The following were elected members of the Society:—

Mr. D. J. Walsh, 3563 Quesnelle Drive, Vancouver, B.C.

Mr. C. H. Thomas, 1510 King St. W., Toronto.

The chairman called on the lecturer of the evening, Prof. A. T. DeLury, to speak on the subject, "The Mathematical Prelude to the Theory of Relativity." The lecturer, referring to the importance in the science of the day of the theory of relativity, spoke of the mathematical development that became the natural setting for the theory. The attitude towards the space concept fostered by the geometry of Euclid, underwent a change when Lobatchefsky and Bolyai showed that a consistent geometry in which the idea of space was somewhat different from that generally received, could exist. About the same time, the researches and investigations of Gauss in differential geometry, became an important ally to this newer view. Riemann, following up the newer views, put the idea of many dimensions on a surer basis. Later, Minkowski, considering certain difficulties in dynamics, developed the idea of a four-dimensional manifold, in which the three positional elements, x, y, z, and the time element, t, were the four co-ordinates. In these theories, Einstein found a basis for his relativity.

The thanks of the meeting to the lecturer were voiced by Dr. Chant. Discussion followed, in which Mr. W. Gore and Mr. J. R. Gibbs and others took part, and all expressed their appreciation of the most unusual address.

E. J. A. KENNEDY, *Secretary.*

December 3, 1929—The meeting was held in the Physics Building of the University at 8 p.m. Mr. J. R. Collins in the chair.

Mr. H. L. Moyer, 94½ Queenston St., St. Catharines, Ont., and Mr. Alvar Wirtanen, 1627 59th St., Kenosha, Wis., U.S.A., were elected to membership in the Society.

The Assistant Librarian gave the names of new books recently added to the library.

The Chairman stated that Prof. Chant's recent book on Astronomy, *Our Wonderful Universe*, has been translated into German, and a copy was shown.

Prof. Chant called attention to the 8-inch reflector owned by the Society which has not been used for want of suitable housing and facilities; if these were provided some useful work could be done with it.

Prof. R. K. Young addressed the meeting on "The Tides," with special reference to the tides on Lake Huron. Last summer he took a machine which would automatically record the changes of height of the water level. Lantern slides were used to illustrate the subject, and also tracings of the variations. His observations were made at Little Current on Manitoulin Island. The average tide on Lake Huron was found to be about two inches. The tide came, on the average, two hours and 50 minutes after the lunar transit. During periods of thunder showers seiches were also observed. The lake levels also formed a portion of his interesting lecture. (See December JOURNAL, p. 445, for paper in full.)

Mr. W. Gore described an investigation he had made some years ago upon the levels of Lake Ontario, which indicated the existence of a tide.

E. J. A. KENNEDY,
Secretary.

AT OTTAWA

Nov. 1—The opening meeting of the Centre was held in the Victoria Memorial Museum. The President, Mr. C. C. Smith, was in the chair.

Before introducing the speaker of the evening the President explained the relationship existing between Astronomy and Seismology, pointing out that by Astronomy, and more particularly Astrophysics, we learn much of the physical constitution of the stars, while Seismology affords us a means of studying the interior of our own planet.

Dr. R. J. McDiarmid, of the Dominion Observatory, spoke briefly on the sky at this season, and mentioned objects of interest to the amateur astronomer.

Motion pictures and slides were used to illustrate the lectures of the evening; this lecture was given by Mr. L. Don Leet, M.A., of Harvard University, and was entitled, "Earthquakes, Natural and Artificial". The film was one taken by the Pathé Film Company, and was prepared at Harvard University under the joint direction of Dr. Kirtley F. Mather, Mr. Leet and Edward A. Schmitz, an artist who constructed the master diagrams for the animated illustrations.

The following abstract is a description of Mr. Leet's address, and the pictures shown:—

Scenes from the Tokyo, Japan, earthquake of September 1, 1923, and the Santa Barbara, California, earthquake of June 29, 1925, illustrated the damage which results when a severe quake occurs near a heavily populated region. Shallow-seated earthquakes of volcanic origin are not usually recorded far from the source, but can do great damage nearby. Scenes from a volcanic quake in Japan illustrated this. On the other hand, tectonic earthquakes are usually accompanied by the violent release of energy which is propagated through and around the entire globe. Animated drawings illustrated the surface faulting which accompanied the Mino-Owari earthquake of Japan in 1891. An animated block diagram showed the nature of the

strains preceding and the elastic rebound following a fracturing of the earth's crust.

Various types of seismographs were pictured, and the principle of a horizontal pendulum was demonstrated with the aid of a small experimental model. The movement of earth particles in longitudinal, transverse, and surface waves was illustrated from a working model.

Animated drawings were also used to show the paths of vibrations from an earthquake as they pass through the earth, some penetrating the central core; the passage of selected rays of longitudinal, transverse, and surface waves from an earthquake in California to recording stations at St. Louis and Boston, where the resultant records appeared; the method of determining distance from the same records; and the location of the epicentre.

Coloured lantern slides were used to illustrate the remainder of the lecture. Some were obtained through the courtesy of the Tokyo Imperial University, Department of Geology; the others were from photographs by the speaker.

A few stills of Yokohama and Tokyo before and after September 1, 1923, supplemented the scenes in the motion picture. There followed a description of landslide phenomena at and near the village of Nebukawa, Japan, on the coast surrounding Sagami Bay, embraced by the epicentral zone of the same earthquake. Evidence was included pertaining to the behaviour of railway tunnels in the affected region.

The presentation was closed by a brief description of the manner in which principles of seismology are being applied to the search for oil structures. Salt domes, in particular, are sought as structures favourable to the accumulation of oil. The introduction of seismic methods in the Gulf Coast region of the States is estimated to have advanced the discovery of salt domes by at least 75 years. In fact, many of the domes thus found would probably never have been discovered in any other way. Fifty domes were reported discovered between the start of seismic methods, in 1924, and 1928. The cash value of a dome on discovery, *exclusive of the potential value of any commercial deposits which may be discovered on it*, runs from $150,000 to as high as $500,000. The cost of discovery by old methods averaged over $300,000 per dome. It rarely exceeds half that by seismic methods. The costs of operating a standard seismograph party in the field are estimated to lie between $15,000 and $20,000 per month. There are 28 parties listed as active in the fall of 1928. Thus it may be seen that seismology, through artificial earthquakes, has become a commercial factor of no mean proportions.

A discussion took place after Mr. Leet's address, and the lecturer very kindly answered many questions.

In closing the meeting, Mr. Smith expressed to Mr. Leet, the sincere thanks of the Society for his most interesting and instructive address.

Nov. 29—The second meeting of this season was held in the Victoria

Memorial Museum. R. Meldrum Stewart, M.A., director of the Dominion Observatory, Ottawa, was the speaker.

Before introducing the lecturer, Mr. Smith, the president, made a few remarks about the sky for the winter months, pointing out the most prominent constellations and celestial objects visible at this time of the year.

Mr. Stewart's lecture was entitled, "What is a Star"?, and he dealt with this difficult subject in a most interesting manner.

A few words on the structure of the Universe served as an introduction to the lecture itself, following which Mr. Stewart dealt with the ordinary characteristics of the stars—their brightness, surface temperature, size, mass and density.

A summary of the lecture, which was illustrated with numerous diagrams, follows:—

The real brightness of a star can be found from its apparent brightness, by taking account of the distance. It is found that the stars vary greatly in this respect. The faintest known gives out only one fifty-thousandth as much light as the sun, while some of the brightest are a hundred thousand times brighter than the sun.

The individual surface temperatures are deduced by known laws of physics from the differences between visual and photographic brightness, and by the distribution of energy in the spectrum. The coolest red stars have a surface temperature of 2200°C, the hottest Class O stars from 30000°C to 40000°C. The surface temperature of our sun is intermediate, being about 6000°C. For comparison, the hottest part of a carbon arc is about 3800°C.

The surface brightness (per unit area) of a star can be found from the temperature. Knowing the total brightness, it is easy to compute the area or diameter. The smallest known star is only about the size of the earth, while the largest known (Antares), has five hundred times the diameter of the sun, or about one hundred million times its volume.

The masses or weights of the stars are deduced from measurements of the orbits of double stars. They are more nearly uniform than the other physical properties, varying only from one-tenth of the sun's mass to fifty or a hundred times that quantity.

The density (readily deduced from mass and volume) is the quantity that varies most widely in different stars. The density of the sun is slightly greater than that of water. The density of Antares, which has thirty times the mass of the sun, is one three-millionth that of water, or one three-thousandth that of air; on the other hand, the smallest star mentioned above has a density of 400000, so that a cubic inch of its material would weigh seven tons. This is explained by the assumption that under the enormous temperatures existing in the interior of the stars, the atoms are stripped of their electrons, and can be packed much more closely.

The ages of the stars can be estimated by several different methods.

On the average they are probably between five and ten millions of millions of years. The age of the earth, as deduced from radio-active minerals, is about two thousand million years, with life existing in some form for about half that period, and man for perhaps three hundred thousand years.

Formerly it was thought that the energy radiated from the sun and other stars was replenished by shrinkage due to gravitational attraction. But this could not have kept the sun going for more than fifteen million years. Since the earth has existed for two thousand million, it is obvious that gravitation is entirely inadequate. We can only conclude that in the interior of the stars there is some process at work with which we are entirely unfamiliar—perhaps the actual transformation of matter into energy. The theory of relativity indicates the possibility of such transformation, and it has been tentatively adopted as a working hypothesis by astronomers. The enormous store of sub-atomic energy existing in all matter is exemplified by the fact that, could we make use of it, a single lump of coal would heat the city of Ottawa for a whole season.

Mr. Smith expressed the thanks of the Society to Mr. Stewart for his most interesting lecture.

M. S. BURLAND, *Secretary.*

AT MONTREAL

Oct. 31—The first meeting for the 1929-30 season was held in the Macdonald Physics Loboratory at 8.15 p.m. The President, Dr. A. H. MacCordick, occupied the chair. The annual reports of the Secretary and Treasurer were read.

The election of officers for the present year resulted as follows:

Honorary President: Mgr. C. P. Choquette

President: Dr. A. H. MacCordick

1st Vice-President: Dr. J. B. McConnell

2nd Vice-President: Dr. Julian C. Smith

Secretary Treasurer: Dr. A. Vibert Douglas.

Council: Mr. Asbury, Mr. Armand, Mr. Browning, Miss J. Fleet, Dr. A. S. Eve, Judge E. E. Howard, Mr. Luttrell, Col. W. E. Lyman.

Three new members were elected:—Mr. Fred Turnau, Miss E. Bradburn, Mr. E. Vincelli.

Dr. Eve moved a vote of thanks to the retiring treasurer, Prof. A. J. Kelly, and to the auditors, Mr. Justice E. E. Howard, and Col. W. E. Lyman.

Judge Howard referred to the loss sustained by the society in the deaths of two of its oldest members, Mr. Geo. Sample, and Mr. Jas. A. Wright, and a motion of sympathy with their relatives was passed.

The President then expressed the gratitude of the Society to the Director of the Physics Department, for his generous offer of the use of the Physics Lecture Theatre for the meetings of the Society.

The President thanked the Press for their interest in the meetings, and

expressed the hope that they would report the meetings carefully and enthusiastically in the future as in the past.

The lecturer of the evening was Mr. E. A. Hodgson, Dominion Seismologist, who took for his subject, "The Earth Beneath—in the light of modern Seismology". He gave a very interesting account of the various waves set up within the earth, (P,S,L_r) as a result of an earthquake, and the way in which the times of their arrival at various parts of the earth's surface provide information as to the interior of the earth, the *sial, sima* and *nife*. A full account of this lecture will appear in the Journal R.A.S.C.

The slides and film made at Harvard made a valuable addition to the lecture.

A warm vote of thanks was tendered to the lecturer by Dr. H. T. Barnes.

A. VIBERT DOUGLAS, *Secretary.*

Victoria, Dec. 10, 1929—The Annual Meeting of the Victoria Centre was held in the Girl's Central School, Fort St., at 8.00 p.m. The President, J. A. Pearce, in the chair.

The following were elected members of the Society:

C. R. Charters, Barnet, B.C.
Cyril Jones, 617 Fort St., Victoria, B.C.
Mrs. E. M. Kenmuir, Alert Bay, B.C.

Messrs. R. Bewell and N. C. Stewart were appointed scrutineers, to count the ballots for the election of the 1930 officers.

In the unavoidable absence of the Secretary, Dr. C. S. Beals presented Mr. Gage's reports for the year, and on motion the reports were received and adopted.

The President commented upon the Secretary's report. From the point of view of numbers the past year was the best year in the history of the Society, 28 members being elected. Illustrating his remarks by lantern slides, the growth of the Centre from its organization in 1914 was shown. Another slide compared the financial status of the Society, year by year since 1914. A comparison of the activities of the six Centres of the Society since 1912, was most interesting. Montreal with 112 members, and Victoria with 113, are leading the other Centres with a fair margin. The President urged the members to maintain their position and to make greater gains during 1930.

The Librarian presented his report, which showed that some 65 books had been presented to the library during the present year.

Dr. J. S. Plaskett described the progress which had been made in the construction of the 200-inch telescope. Mirrors of fused quartz up to 22-inches in diameter, have been successfully cast. The proposed method of annealing the giant 200-inch mirror and the many difficulties to be overcome were explained.

The scrutineers reported the result of the election as follows:

Honorary President:	W. E. Harper, M.A., F.R.S.C.
President:	Dr. C. S. Beals, Victoria, B.C.
First Vice-President:	Dr. G. M. Shrum, Vancouver, B.C.
Second Vice-President:	W. H. Gage, M.A., Victoria, B.C.
Secretary-Treasurer:	P. H. Hughes, Victoria, B.C.
Librarian:	W. T. Bridge, Victoria, B.C.
Council:	G. A. Bucklin, Victoria, B.C.
	Rev. J. Goodfellow, M.A., Princeton, B.C.
	J. P. Hibben, Victoria, B.C.
	R. W. Hunter, Victoria, B.C.
	Mrs. M. A. Kelk, Alert Bay, B.C.
	and past Presidents.

The retiring President thanked the officers and members of the Council for their support during the past years, and then called upon Dr. C. S. Beals to take the chair.

The address of the evening was then given by the retiring president upon the subject: The Rotation of the Galaxy.

The speaker briefly reviewed the conceptions of the size and structure of the Galaxy which Herschel, Newcomb and other astronomers of the nineteenth century held. The researches and discoveries of the modern astronomers, such as Kapteyn, Van Maanen, Shapley and Hubble were outlined, thus leading to the present conception of the size of the Galaxy, and to the belief that the spiral nebulae are external galaxies.

Lindblad's hypothesis that the Galaxy was in rotation was explained, and it was shown that this assumption would account for the motions of the high velocity stars, and the asymmetry of stellar motions as discovered by Stromberg. The confirmation of the rotation was first demonstrated by Oort, who showed that in consequence of a rotation there would be a double-wave in the proper motions and the radial velocities of the stars.

The lecture closed with a discussion of the analysis of the motions of the O- and B-type stars observed at Victoria by Plaskett and Pearce. The radial velocities of 875 stars, of which number approximately 460 have been recently determined by the investigators, provide conclusive evidence that the Galaxy is in rotation about an axis perpendicular to the plane of the Milky Way, the centre of motion being in galactic longitude 325 degrees, in the direction of the constellation of Sagittarius. The distance to the centre is approximately 20,000 parsecs, or 60,000 light years. The sun and nearby stars of our local cluster are revolving in a circular orbit about this centre, the velocity of the sun being 300 km. per sec., thus making the period of one revolution approximately 100,000,000 years.

The lecture was illustrated by many diagrams and photographs.

WALTER H. GAGE,
Secretary.

AT LONDON

Annual Meeting.—The Annual Meeting of the London Centre was held in the Normal School, Dr. Kingston in the chair.

After voting in three new members the Secretary's and Treasurer's reports were read and adopted.

The meeting then adjourned and reconvened for the election of officers for 1930, Mr. McKone in the chair.

The following officers were elected:

President—Dr. H. R. Kingston (acclamation), 287 Oxford St., City.

Vice-Pres.—Mrs. S. J. Berry, 633 Waterloo St., City.

Secretary-Treasurer—Dr. H. S. Wismer, 253 Queen's Ave., City.

Council:—Rev. R. J. Bowen, Miss A. Callard, Mr. E. H. McKone, Mr. T. C. Benson, and Mr. W. E. Saunders.

Dr. Kingston then resumed the chair and the meeting was carried on as the regular December meeting.

H. S. WISMER,
Secy.-Treas.

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(*a*) "To study Astronomy, Astrophysics and such cognate subjects as shall be approved of by the Society and as shall, in its opinion, tend to the better consideration and elucidation of Astronomical and Astrophysical problems; and to diffuse theoretical and practical knowledge with respect to such subjects.

(*b*) To publish from time to time the results of the work of the Society; and,

(*c*) To acquire and maintain a Library, and such apparatus and real and personal property as may be necessary and convenient for the carrying into effect of the objects of the Society."

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Ont.; Toronto, Ont.; London, Ont.; Winnipeg, Man.; and Victoria, B.C. Among its 800 members are a number of the leading astronomers and scientists of the world, many amateurs, and in addition, many laymen who are interested in the culture of the science.

Membership in the Society is open to anyone interested in Astronomy. The annual dues are $2.00; life membership $25.00 (no further dues). The annual fee includes subscription to the publications.

The Society publishes a monthly JOURNAL containing about 500 pages of interesting articles, and the yearly HANDBOOK of 72 pages containing valuable information for the amateur observer. Single copies of the JOURNAL or HANDBOOK are 25 cents.

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